ity, cloudiness, and forest-fire hazard suggest the importance of a cloud "weather eye" to patrolmen. By estimation of the cloudiness, the probable hazard can be estimated. By summation of the average cloudiness since the last rainfall a better estimate of its effect on reducing the fire hazard is probable. The mean cloudiness of a given region will aid in relating the hazard in that region as compared with other regions. Similarly, the amount of given cover on a cut-over area will be an important criterion of the hazard it presents.

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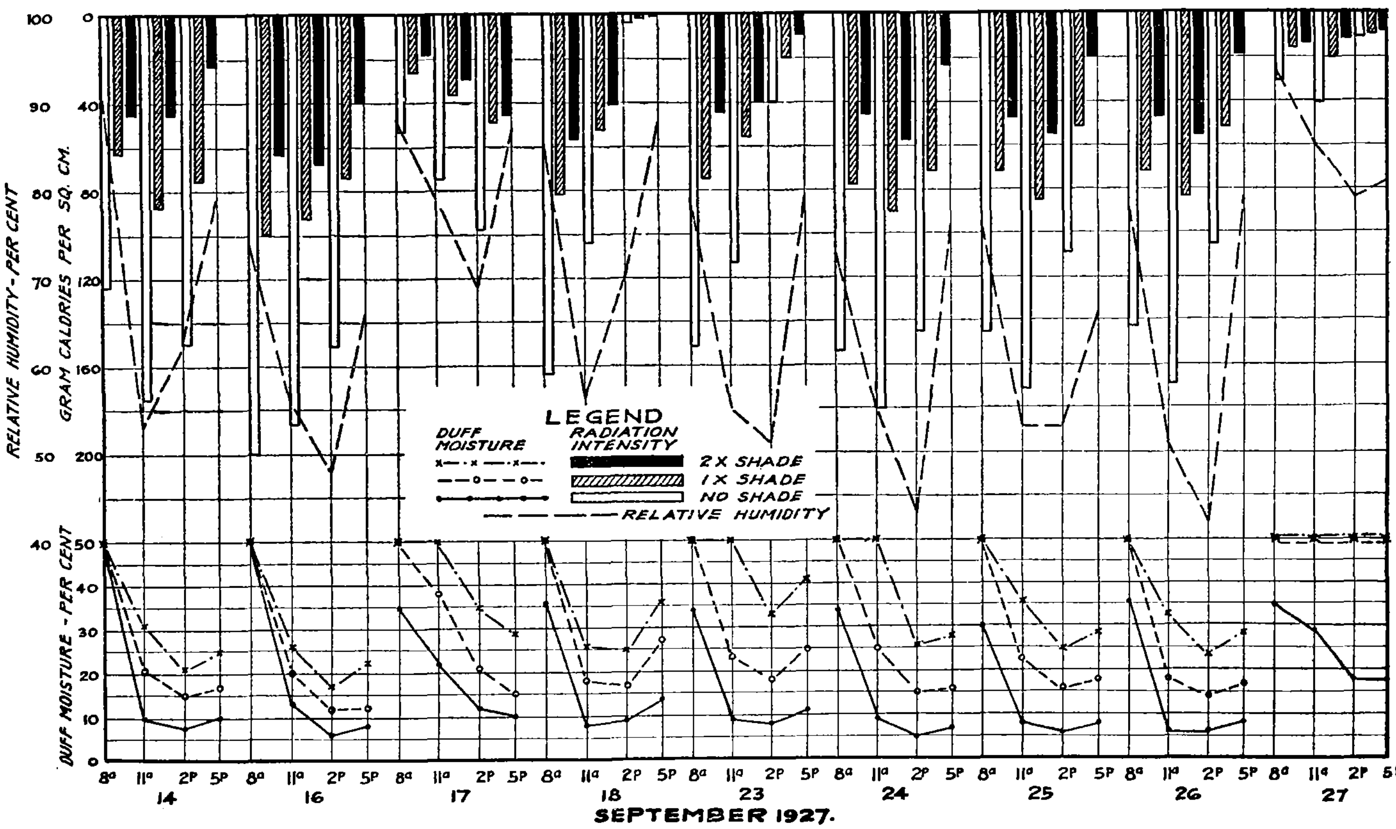
FIGURE I.



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DURATION OF RAINFALL AT HAVRE, MONTANA

By FRANK A. MATH

[Weather Bureau Office, Havre, Mont., October 23, 1929]

As the duration of precipitation in various parts of the United States is of much interest to forecasters, aviators, farmers, and business men in general, and as information of the kind so far published is for stations in the Atlantic States, it seemed desirable to prepare the data for a station in the semiarid plains region of the far Northwest.

The duration of precipitation for each hour during the 10-year period 1919–1928 was compiled for Havre, Mont., and entered on suitable forms. One form holds a month's record. All beginnings and endings of precipitation were considered and all intervals between rains were eliminated. The total for each day in hours and tenths were counted. Then the monthly totals were computed. Two compilations were made. The first, Table No. 1, includes every occurrence of precipitation recorded on Form 1014; the second, Table No. 2, includes only the hours in which 0.01 inch or more was recorded.

During the winter season in this section from November 1 to April 1, practically all of the precipitation occurs in the form of snow, and automatic registration is impracticable. Since the winter 1926–27 the observer has estimated the hourly amounts of snow as it fell during the awake hours. Previous to that time the hourly amounts, for this paper, were estimated as well as possible from the beginnings and endings and the 12-hour amounts. There are many times during zero weather in winter that light fluffy dry snow falls continuously for 12 to 24 hours, amounting to only a trace or 0.01 inch, the last hour usually being credited with the 0.01. When more than 0.01 was recorded the amount was reasonably distributed throughout the period.

In the 10-year period which was tabulated it was found that the average total precipitation hours for the year is 720 when traces are counted and only 386 when traces are omitted. This indicates that for the total time precipitation occurs at Havre, slightly more than half (54 per cent) is at the rate of only a trace an hour. There are considerably more hours in winter with only a trace than in summer. During the cold months, October to March, inclusive, the average total precipitation hours including traces are 412, while those with 0.01 inch or more are 180, or 232 hours of only a trace. On the other hand, the warm months, April to September, inclusive, show 308 hours with traces included and 206 with traces omitted, or only 102 trace hours. Also during the warm six months with a normal rainfall of 10.27 inches the duration averages 308 hours, including traces, whereas during the cold six months with a normal precipitation of only 3.63 inches the duration averages 412 hours, which is 104 hours more time and 6.64 inches less precipitation. However, from Table No. 2, counting only hours with 0.01 or more, the summer half year averages 206 hours against 180 hours in the winter half. This conforms with statements by Henry and Tannehill (MONTHLY WEATHER REVIEW, April, 1929, p. 139): "The intensity of precipitation is greatest in warm months and least in cold months." Also, "A greater time is required for a given amount of rain to fall in cold periods than in warm, and the period of attendant cloudiness is extended."

An inspection of the monthly averages, Table No. 2, reveals that the peak of greatest duration of precipitation occurs during the month of June. This is also the wettest month. From the June peak there is a rapid falling off during July and August, which, however, is followed again by a sudden increase in precipitation hours during September. Then another low period in October, known as Indian summer, precedes the winter snows. Inhabitants living in this section for a number of years look forward to the September rainy period, which is usually accompanied by a cool spell with probably snow. It is generally attended by frosts and freezing.

A further study shows the duration of precipitation at Havre is extremely variable at all seasons. For a typical winter month, as January, the total number of precipitation hours, trace hours omitted, ranges from 10 to 61 hours; May, from 6 to 162 hours; July, from 5 to 42 hours; November, from 0 to 75 hours. The greatest monthly number of precipitation hours in the 10-year period was 162 in May, 1927, the least 0 in November, 1925. The greatest annual number was 559, in 1927, and the least 301, in 1928.

Computing percentages for Tables Nos. 1 and 2 and tabulating the results, precipitation is occurring at Havre on the average during the year as follows:

	Per cent											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Trace hours included	8.9	10.6	10.8	9.3	8.0	8.7	4.2	3.6	8.3	5.3	9.2	11.7
Trace hours omitted	3.9	4.6	4.8	5.4	5.5	6.5	3.1	2.5	5.2	2.3	4.6	4.7

By making a tabulation showing the average duration of precipitation, trace hours omitted (Table No. 3), throughout the 24 hours of the day in the different months for the 10-year period, also for the warm half of the year (April–September, inclusive, Table No. 4) and the cold half (October–March, inclusive, Table No. 5), it is found that during the warm six months, which period is the growing season, and most of the rains were registered by the automatic tipping bucket rain gage, the duration of precipitation is greatest for the hour 11 p. m. to midnight. It is twice as long as in the hour from 2 to 3 p. m. There is remarkably greater length of precipitation time during the night hours from 7 p. m. to 4 a. m. than during the daylight hours. While the hour from 2 to 3 p. m. has the least duration, the other afternoon hours between noon and 7 p. m. have considerably less than the night hours. This shows that there is a predominance of nighttime precipitation hours over daytime in this section. Kincer has shown (vol. 44, MONTHLY

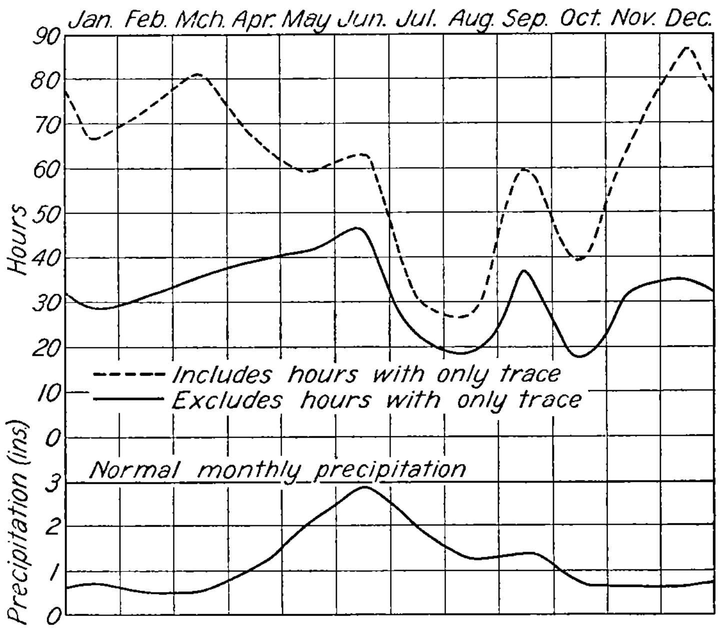

FIGURE 1

WEATHER REVIEW, 1916, pp. 628–633) that such is true generally for the summer season in the Central Plains region. This is probably due, to a great extent, to the large diurnal range in temperature over the plains. The rapid rise in temperature shortly after sunrise expands the air to such a degree that the moisture content is readily absorbed. The relative humidity falls to a low point during the daytime hours.

The duration during the winter half of the year is more uniform during the 24 hours. While the summer period ranges from 1.0 between 2 and 3 p. m. to 2.0 between 11 p. m. and midnight, the winter season ranges from 1.0 between 9 and 10 a. m. to 1.5 between 7 and 10 p. m. During the winter season there is no automatic hourly registration. The diurnal range in temperature is not so pronounced.

Figure No. 2 shows a comparison of the percentage of rainy hours with those of bright sunshine. Sunny weather occurs at Havre thirteen times as much of the possible time as rainy weather. It must be remembered also that, while rain may occur any time during the 24 hours, sunshine is limited to the hours that the sun is above the horizon, or about one-half of the time. The rainfall percentage of possible for the year is 4.4, while the sunshine hours total 58 per cent of the possible.

Other data on the duration of precipitation have been published for two Atlantic seaboard stations—Baltimore, by Nunn, in MONTHLY WEATHER REVIEW, February, 1929, and Philadelphia, by Mindling, in MONTHLY WEATHER REVIEW, November, 1918. A comparison of

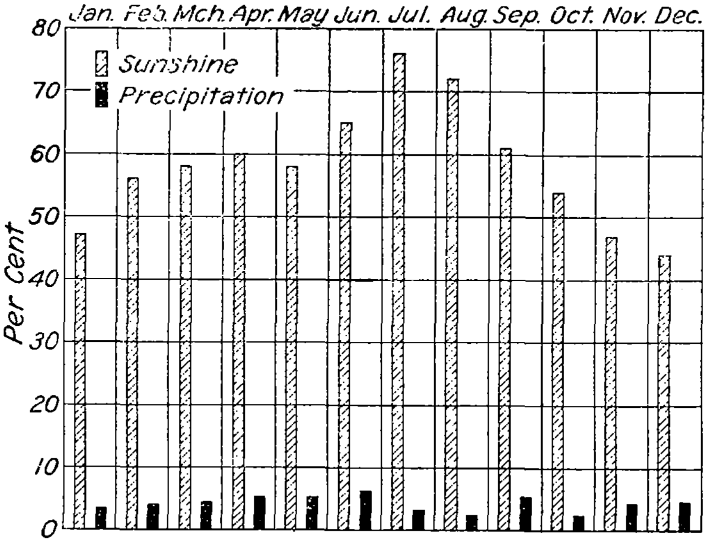

FIGURE 2

some of the Havre data with similar data taken from the above-mentioned literature follows:

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Annual
	10-year average precipitation hours, excluding traces												
Baltimore	63.9	59.0	62.9	57.4	44.2	29.4	32.3	39.7	31.1	34.5	42.3	60.5	557.2
Havre	28.7	30.8	35.6	39.0	40.7	46.8	23.0	18.8	37.1	17.1	33.1	34.7	385.6
	Daily average												
Baltimore	2.1	2.1	2.0	1.9	1.4	1.0	1.0	1.3	1.0	1.1	1.4	2.0	1.5
Havre	0.9	1.1	1.1	1.3	1.3	1.6	0.7	0.6	1.2	0.6	1.1	1.1	1.1

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Annual
	10-year average precipitation hours, including traces												
Philadelphia	119.1	108.0	103.1	101.0	76.0	59.8	41.0	54.6	46.5	59.3	70.0	101.7	940.1
Havre	66.3	72.1	80.6	67.2	59.5	62.8	31.0	27.1	60.0	39.6	66.5	87.0	719.7
	Daily average												
Philadelphia	3.8	3.5	3.3	3.3	2.4	1.9	1.3	1.8	1.5	1.9	2.3	3.3	-----
Havre	2.1	2.6	2.6	2.2	1.9	2.2	1.0	0.9	2.0	1.3	2.2	2.8	-----

The greatest monthly number of precipitation hours, omitting traces, in the 10-year period for Baltimore was 114 hours, during April, 1918; Havre, 162 hours, May, 1927; the least for Baltimore, 1.8 hours, October, 1924; Havre, 0, November, 1925. The greatest annual number of hours for Baltimore was 637, in 1920; Havre, 559 in 1927; and the least for Baltimore was 502 in 1925; Havre, 301 in 1928.

As was expected the duration of precipitation at Havre. as a rule, is much shorter than at the Atlantic stations, however, there is a peculiar exception during the months of June and September, when Havre shows greater duration.

ACKNOWLEDGMENT

Mr. Roscoe Nunn read the manuscript of this paper and offered a few suggestions, which were followed.

TABLE No. 1.—*Total duration (hours) of precipitation at Havre, Mont., excluding hours with only traces, 1919 to 1928, inclusive*

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1919	21.2	80.2	57.2	15.0	24.2	29.5	4.4	10.8	36.5	40.2	41.6	17.0	377.8
1920	61.3	24.4	34.6	87.0	36.1	31.2	16.9	20.3	19.4	19.9	2.6	34.0	387.7
1921	10.0	10.4	84.2	36.5	41.0	27.9	43.3	5.4	56.0	2.8	55.1	19.0	391.6
1922	36.2	52.2	29.4	42.3	60.6	26.1	35.2	7.0	23.1	5.0	42.2	37.0	396.3
1923	32.1	18.7	4.4	47.8	21.1	67.1	34.5	22.1	19.1	9.7	9.0	22.4	308.0
1924	25.8	26.0	54.1	31.1	25.4	70.8	13.7	12.7	23.8	15.4	34.0	70.9	403.7
1925	31.3	28.0	43.0	54.8	9.8	71.9	16.3	20.8	81.8	34.6	0.0	31.0	423.3
1926	17.0	16.0	4.5	6.6	20.9	38.0	5.1	23.7	78.0	2.8	70.1	24.5	307.2
1927	39.0	41.0	23.9	38.7	161.8	26.4	42.9	13.4	22.1	30.4	74.8	45.0	559.4
1928	13.4	11.0	21.2	30.5	6.5	79.6	18.2	51.6	11.1	9.8	2.0	45.8	300.6
Means	28.73	30.79	35.64	39.03	40.74	46.85	23.05	18.78	37.09	17.06	33.14	34.66	385.56
Per cent	3.9	4.6	4.8	5.4	5.5	6.5	3.1	2.5	5.2	2.3	4.6	4.7	-----

TABLE No. 2.—*Average total duration (hours) of precipitation, excluding traces, Havre, Mont., 1919–1928*

Month	A. M.												P. M.												Tota:
	1	2	3	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	10	11	Mid-night	
January	1.7	1.6	1.5	1.1	0.7	0.7	0.7	0.5	0.9	1.0	1.4	1.3	1.2	0.8	1.4	0.8	1.3	1.0	1.1	1.2	1.6	1.9	1.5	2.0	28.73
February	0.8	1.1	1.1	1.5	1.4	1.2	1.1	1.0	1.2	0.8	1.3	1.2	1.2	0.8	0.9	1.2	1.4	1.5	1.8	1.9	1.8	1.7	1.7	1.2	30.79
March	1.7	1.8	1.6	1.6	2.1	1.5	1.1	1.1	1.0	1.3	1.2	1.1	0.9	1.7	1.2	1.0	1.4	1.3	1.4	2.1	1.7	1.9	2.0	1.9	35.64
April	1.8	2.2	2.1	2.1	1.7	1.4	1.4	1.6	1.4	1.4	1.2	1.6	1.2	1.2	1.2	1.4	1.0	1.2	1.4	1.9	1.7	2.2	2.2	2.5	39.03
May	2.1	2.1	1.6	1.7	1.4	1.8	1.0	1.4	1.3	1.7	1.4	1.4	1.2	1.2	1.1	1.4	2.1	2.1	1.6	2.5	1.9	2.3	2.2	2.1	40.74
June	2.2	2.3	2.2	2.4	2.1	1.9	2.0	1.8	2.0	1.4	1.3	1.4	1.5	2.0	1.5	1.6	1.8	1.9	1.6	1.9	2.3	2.5	2.8	2.4	46.85
July	1.7	1.4	1.4	1.2	0.7	0.7	0.8	1.0	0.9	0.7	0.7	0.8	0.6	0.7	0.6	0.9	0.6	0.6	0.5	1.2	1.2	1.1	1.3	1.8	23.05
August	0.8	1.0	1.0	0.9	0.8	0.9	0.8	0.8	1.0	0.8	1.0	0.8	0.5	0.6	0.2	0.4	0.6	0.7	0.6	0.9	0.8	1.1	1.0	0.7	18.78
September	1.9	1.7	1.8	1.7	1.8	1.9	1.5	1.6	2.2	1.5	1.3	1.2	1.5	1.1	1.1	1.2	1.2	1.0	1.0	1.5	1.6	1.6	1.9	2.2	37.09
October	0.5	0.7	0.6	0.9	0.7	1.0	1.1	0.7	0.7	0.8	0.8	0.7	0.5	0.8	0.6	0.7	0.6	0.7	0.7	0.8	0.6	0.7	0 9	0.4	17.06
November	0.6	0.7	1.5	1.7	2.0	1.1	1.3	1.5	1.5	1.3	1.4	1.9	1.6	2.0	1.8	1.5	1.6	1.3	1.4	1.1	1.4	1.4	0.8	0.9	33.14
December	1.3	1.3	1.4	1.4	1.7	1.4	1.7	1.6	1.3	1.1	1.0	1.6	1.6	1.1.	1.6	1.4	1.6	1.3	1.0	2.0	1.8	1.5	1.6	1.3	34.66
Total	17.1	17.9	17.8	18.2	17.1	15.5	14.5	14.6	15.4	13.8	14.0	15.0	13.5	14.0	13.2	13.5	15.2	14.6	14.1	19.0	18.4	20.0	19.9	19.4	------
Mean	1.4	1.5	1.5	1.5	1.4	1.3	1.2	1.2	1.3	1.2	1.2	1.2	1.1	1.2	1.1	1.1	1.3	1.2	1.2	1.6	1.5	1.7	1.7	1.6	------

TABLE No. 3.—*Duration of precipitation (hours) during the crop growing season at Havre, Mont., April 1, to September 30, trace hours omitted (automatic registration)*

Month	A. M.												P. M.												Total
	1	2	3	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	10	11	Midnight	
April	1.8	2.2	2.1	2.1	1.7	1.4	1.4	1.6	1.4	1.4	1.2	1.6	1.2	1.2	1.2	1.4	1.0	1.2	1.4	1.9	1.7	2.2	2.2	2.5	39.03
May	2.1	2.1	1.6	1.7	1.4	1.8	1.0	1.4	1.3	1.7	1.4	1.4	1.2	1.2	1.1	1.4	2.1	2.1	1.6	2.5	1.9	2.3	2.2	2.1	40.74
June	2.2	2.3	2.2	2.4	2.1	1.9	2.0	1.8	2.0	1.4	1.3	1.4	1.5	2.0	1.5	1.6	1.8	1.9	1.6	1.9	2.3	2.5	2.8	2.4	46.85
July	1.7	1.4	1.4	1.2	0.7	0.7	0.8	1.0	0.9	0.7	0.7	0.8	0.6	0.7	0.6	0.9	0.6	0.6	0.5	1.2	1.2	1.1	1.3	1.8	23.05
August	0.8	1.0	1.0	0.9	0.8	0.9	0.8	0.8	1.0	0.8	0.8	0.8	0.5	0.6	0.2	0.4	0.6	0.7	0.6	0.9	0.8	1.1	1.0	0.7	18.78
September	1.9	1.7	1.8	1.7	1.8	1.9	1.5	1.6	2.2	1.5	1.3	1.2	1.5	1.1	1.1	1.2	1.2	1.0	1.0	1.5	1.6	1.6	1.9	2.2	37.09
Sum	10.5	10.7	10.1	10.0	8.5	8.6	7.5	8.2	8.8	7.5	6.9	7.2	6.5	6.8	5.7	6.9	7.3	7.5	6.7	9.9	9.5	10.8	11.4	11.7	
Mean	1.8	1.8	1.7	1.7	1.4	1.4	1.2	1.2	1.5	1.2	1.2	1.2	1.1	1.1	1.0	1.2	1.2	1.2	1.1	1.6	1.6	1.8	1.9	2.0	

TABLE No. 4.—*Duration of precipitation (hours) during the winter season, at Havre, Mont., October 1 to March 31, trace hours omitted (hourly amounts estimated)*

Month	A. M.												P. M.												Total
	1	2	3	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	10	11	Midnight	
October	0.5	0.7	0.6	0.9	0.7	1.0	1.1	0.7	0.7	0.8	0.8	0.7	0.5	0.8	0.6	0.7	0.6	0.7	0.7	0.8	0.6	0.7	0.9	0.4	17.06
November	0.6	0.7	1.5	1.7	2.0	1.1	1.3	1.5	1.5	1.3	1.4	1.9	1.6	2.0	1.8	1.5	1.6	1.3	1.4	1.1	1.4	1.4	0.8	0.9	33.14
December	1.3	1.3	1.4	1.4	1.7	1.4	1.7	1.6	1.3	1.1	1.0	1.6	1.6	1.1	1.6	1.4	1.6	1.3	1.0	2.0	1.8	1.6	1.6	1.3	34.66
January	1.7	1.6	1.5	1.1	0.7	0.7	0.7	0.5	0.9	1.0	1.4	1.3	1.2	0.8	1.4	0.8	1.3	1.0	1.1	1.2	1.6	1.9	1.5	2.0	28.73
February	0.8	1.1	1.1	1.5	1.4	1.2	1.1	1.0	1.2	0.8	1.3	1.2	1.2	0.8	0.9	1.2	1.4	1.5	1.8	1.9	1.8	1.7	1.7	1.2	30.79
March	1.7	1.8	1.6	1.6	2.1	1.5	1.1	1.1	1.0	1.3	1.2	1.1	0.9	1.7	1.2	1.0	1.4	1.3	1.4	2.1	1.7	1.9	2.0	1.9	35.64
Sum	6.6	7.2	7.7	8.2	8.6	6.9	7.0	6.4	6.6	6.3	7.1	7.8	7.0	7.2	7.5	6.6	7.9	7.1	7.4	9.1	8.9	9.2	8.5	7.7	
Mean	1.1	1.2	1.3	1.4	1.4	1.2	1.2	1.1	1.1	1.0	1.2	1.3	1.2	1.2	1.2	1.1	1.3	1.2	1.2	1.5	1.5	1.5	1.4	1.3	

551.576

UTILIZATION OF FIXED SEARCHLIGHTS IN MEASURING CLOUD HEIGHTS

By IRVING F. HAND

[Weather Bureau, Washington, November 6, 1929]

For the past few weeks the writer has been making cloud-height determinations by means of the angular measurement of the location of a spot of light cast upon clouds by a powerful searchlight. The merit of the method, if there be any, lies in the simplicity, rapidity, and accuracy of the measurements, as the cloud height at any given time may be determined in less than a minute.

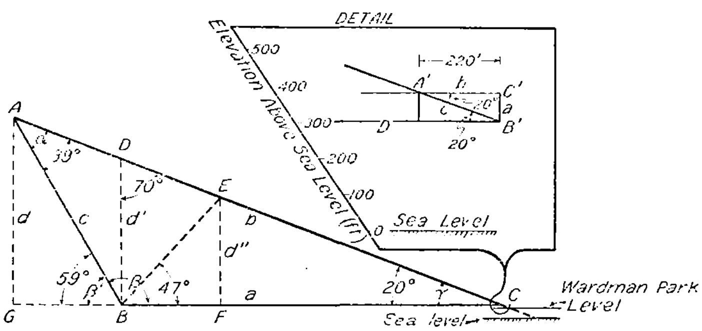

FIGURE 1.—Triangle formed by base line, BC, light beam, CA, and line of sight, BA

The searchlight utilized for this purpose is at an elevation of 300 feet on top of the Wardman Park Hotel, District of Columbia, and swings in a circle 20° from the horizontal once every 25 seconds. The method consists in measuring the altitude of the spot of light when it is in a vertical plane including the point of observation and the source of light. Simple triangulation then shows the height of the spot of light, or the cloud height, above ground, sea level, or any other base desired.

The point of observation in the example here cited has been the writer's home in Wesley Heights, D. C., having an elevation of 380 feet and being distant 10,520 feet from a point 80 feet directly over the searchlight. By computing the distance A' C', shown in the insert of Figure 1, by use of the formula $b = a \cot A'$ where $a = (380-300)$ and $A' = 20°$ (fixed elevation of light), we obtain the value of 220 feet, which, subtracted from 10,520 feet, leaves 10,300 as the value of BC in the main drawing of Figure 1, where C represents the point of intersection of the beam of light with the horizontal plane of observation, and B, the point of observation.

To solve for d, we have

$$c = \frac{a}{\sin \alpha} \sin \gamma \text{ and } d = c \sin\beta' = \frac{a \sin \gamma \sin \beta'}{\sin \alpha}.$$

Instead of using the angle α, we may use compliments of angles by substituting $\sin \beta$ for $\sin \beta'$ in the numerator and $\sin (20° + \beta)$ for $\sin \alpha$ in the denominator, whereby we use measured angles for computation. Thus the formula becomes

$$d = \frac{a \sin \gamma \sin \beta}{\sin\ (20° + \beta)} \tag{1}$$

Examples: When $\beta = 121°$, 90°, and 47°, respectively; or greater than, equal to, and less than a right angle.

$\beta = 121°$

log 10300 (a)	=4. 01284	
log sin 20° (γ)	=9. 53405	
log sin 121° (β)	=9. 93307	
colog sin (20°+121)	= . 20113	
Antilog	=3. 68109	d=4798

$\beta = 90°$

log 10300 (a)	=4. 01284	
log sin 20° (γ)	=9. 53405	
log sin 90° (β)	=0. 00000	
colog sin (20°+90)	= . 02701	
Antilog	=3. 57390	d'=3749